PECULIAR FEATURES OF THE WATER REGIME FORMATION ALONG THE CATENA OF THE SODDY-PODZOLIC SOIL

© 2015 N. A. Muromtsev, K. B. Anisimov, I. Savin[1,2], E. Tanov[2], S. Kharzinov[3]

[1]*V. V. Dokuchaev Soil Science Institute, 119017, Moscow, Pyzhevskii per., 7*
e-mail: muromcev39@mail.ru

Under consideration is the dynamics of soil moisture storage and the soil water potential along the catena represented by soddy-podzolic weakly gleyed soil. Peculiar formation of the soil moisture storage and its transformation in time and in dependence on weather conditions was identified in different positions of soil catena. It is shown that the dynamics of soil water potential throughout the soil profile and in time well agrees with peculiar changes in the soil moisture storage.

Keywords: soil catena, soil water, soil moisture storage, soil water potential, tensiometer, groundwater, precipitation.

INTRODUCTION

A considerable part of lands within the southern taiga subzone (in the forest zone) is represented by sloping areas of different elevation and extend. In view of this, every conditionally taken territory can be considered as a differently elevated soil catena. The catena is a toposequence, in which the soils are genetically associated with the action of water flows and gravity [3]. Infrequently, the soil catena is named as an elementary landscape, landscape strip, elementary soil area, microcatena, etc. The soil-ground water serves as an element (index, parameter) connected different parts of gently slope. The water level is rather low in the upper part of catena and high in its lower part, thus predetermining the development of hydromorphism process in lower and middle parts of slope as well as in lower relief forms. Due to natural redistribution of atmospheric precipitation along the slope the different parts of catena reveal varying moistening degrees. With respect to hydrology three basic parts can be distinguished within the catena: the upper (boundary to the plateau), middle and lower as transitional to the foothill of the slope.

The objective of this paper is to study the dynamics of the soil water and its potential with the view of evaluating the water supply of plants and its optimization in different parts of the weakly elevated catena represented by a soddy-podzolic soil.

OBJECT OF RESEARCH AND METHODS

The studies were carried out along the catena represented by the soddy-podzolic weakly gleyed loamy soil in the test field and abandoned lands close to this field at the territory of Zelenogradski experimental station of the V.V. Dokuchaev Soil Science Institute in the Moscow region. The upper part of catena is occupied by the above soil (test plot 1). The middle (test plots 2 and 3) and especially lower (test plot 4) parts in catena display the hydromorphism features at a depth of 50 cm. The particle size distribution shows insignificant differences between the test plots. The upper 0–50 cm soil layer is characterized by medium loam, whereas the underlying (50–100 cm) layer is heavy loamy in texture. In the 0–50 and 50–100 cm layers the bulk density makes up 1.50 and 1.64 g/cm^3 respectively. The maximum hygroscopic water (MHM) is 8.2 and 13.5%, the moisture wilting (MW) – 10.0 and 18.5%, the minimum water capacity (MWC) – 35.3 and 31.4%.

Under study were the following parameters: soil moisture, water potential within the 0–100 cm layer and the other meteorological indices for the layer close to the soil surface. Besides stationary soil-moisture tensiometers a portable tensiometer was used to measure the water potential at a depth of 40 cm. The state of the terrestrial air layer was determined by means of automated meteorological station VantagePro 2.

To determine the soil moisture, 4 plots were taken in the test field sized 2.5 ha. Plot 1 – in the uppermost part of this field, plot 2 – in the middle gently sloping area and somewhat lower than the plot 1, plot 3 – in a closed depression incised by 50 cm deep and located at the same level with plot 2. The plot 4 was on the opposite side of the test field (catena), occupying the lower part of catena and characterizing by the increased level of the soil-ground water that was periodically measured by boring to the depth of 50 cm. In wet years the hydromorphism signs (bluish mottles, veins, Fe–Mn patches and the other pedofeatures) were observed at this depth. Hence, the automorphic component of the soddy-podzolic soil remained only in the upper part of the slope (plot 1), being transformed into the soddy-podzolic semi-hydromorphic (weakly gleyed) loamy soil.

The data about morphogenetic, agrochemical and agrophysical properties of this soil have been earlier obtained and presented in different publications [8, 9]. In the course of our studies the rape together with perennial sainfoin {*Leguminosae*) was cultivated in the test field. The abandoned lands were covered by grass.

The studies were conducted in summer of 2014; it was very hot and dry, the rainfall was rather low especially in July and early-August (about 16 mm in total).

As regards the meteorological parameters it is worth emphasizing that in most cases the values of solar radiation, total evaporation, air temperature and wind velocity were maximal during the vegetation period and only the value of relative air moisture seemed to be minimal. The atmospheric precipitation in June and August (there was practically no rainfall in July) promoted increasing the relative air moisture, decreasing the air temperature, total evaporation and solar radiation.

The rainfall in the period from middle June to October 12, 2014

Time of rainfall	Precipitation, mm	Time of rainfall	Precipitation, mm
17.06–20.06	18.0	27.08	7.0
21.06–04.07	0.5	28.08	1.8
05.07–18.07	4.1	29.08	3.0
30.07	2.2	30.08	1.8
31.07	0.2	01.09	1.2
07.08	32.6	02.09	16.8
08.08	13.4	03.09	0.4
13.08	6.8	14.09	2.6
16.08	0.2	24.09	4.6
17.08	20.2	28.09	0.4
14.08	5.0	30.09	3.6
15.08	3.0	01.10	3.0
22.08	3.2	06.10	0.6
25.08	0.2	11.10	4.8
26.08	0.0		

The daily dynamics of basic meteorological parameters prove to be interrelated and interdependent between each other. The increased solar radiation leads to increasing the total evaporation, air temperature and decreasing its moisture. The rainfall is able to decline the solar radiation to zero, the total evaporation and the air temperature to the minimum, thus increasing the air moisture to a considerable extent. Due to wind intensification the actual evaporation becomes increased but the air moisture is decreased.

The data about the water content in different soil layers are presented in Fig. 1. The soil moisture storage was calculated taking into consideration the fact that the 0–50 cm layer is a layer of intensive water rotation containing 80–85% of plant roots. The upper 0–30 cm layer is especially rich in mineral and organic nutrient elements. The 50–100 cm layer containing a small amount of roots (20–10%) should be considered as a reserve layer to compensate the water and nutrients taken up by plants.

The first boring was performed in early Mai. At this time the hydrological conditions were insufficient in 4 plots. The soil moisture storage in the 0–30 cm layer made up 59, 70, 70 and 71 mm respectively, thus corresponding to 56–67% as averaged to 63% of the minimum water capacity (MWC), the latter being considered as a lower boundary of optimal moisture for many crops. However, in early Mai when the seeding takes place the topsoil (0–10(20) cm) should be more wet for germination. In our experiment the water content in the topsoil was lower as compared to the 0–30 cm layer what speaks about the water deficit. In plot 4 the soil moisture was somewhat higher as compared to plots 1–3 (about 67% of MWC). This is explained by the capillary fringe of the ground water close to the soil surface. The groundwater level seemed to be at a depth of 50 cm and the water content in the 0–50 and 50–100 cm layers was estimated at 70 to 100% of MWC. Then the water content in the 0–30 cm layer of all the plots started to change under the effect of the evaporation and precipitation in the following way: plot 1 < plot 2 < plot 3 < plot 4. The peculiar water distribution in all the plots is explained by their different position in catena what leads to moisture redistribution at the surface of the test field. The parent material for the development of the soddy-podzolic

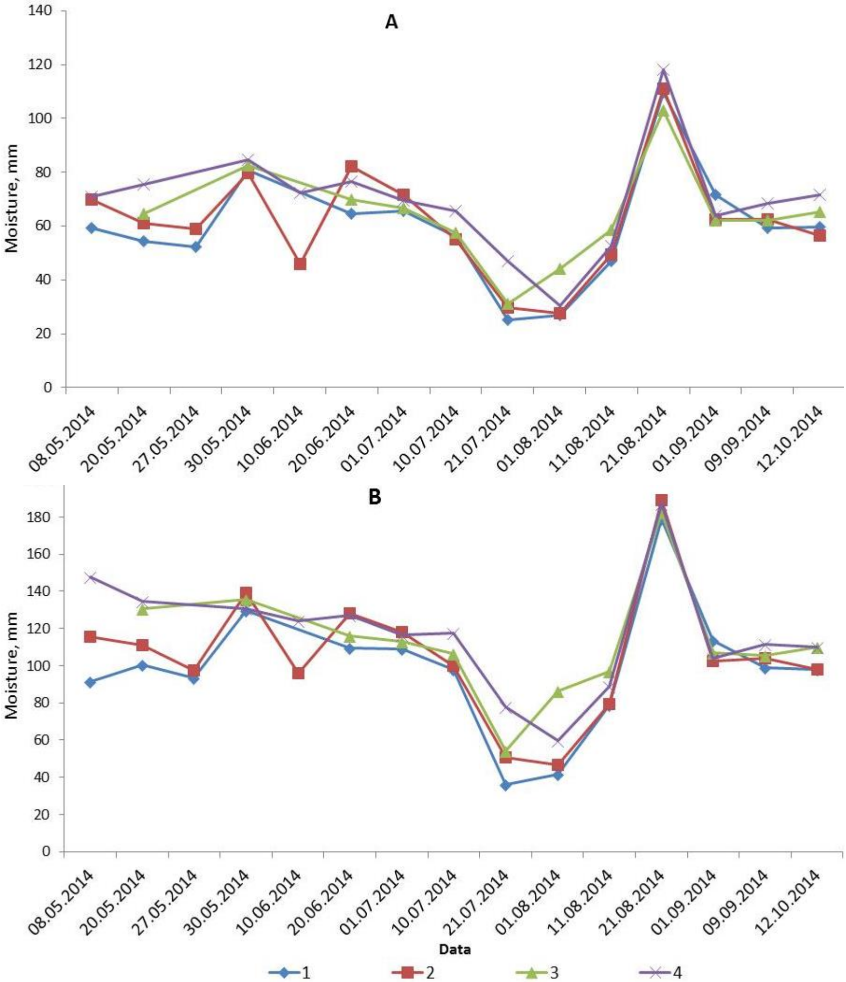

Fig. 1. The water content in the 0–30 cm (A) and 0–50 cm (B) layers of the soddy-podzolic soil within the test plots 1–4.

soil is the mantle that is why the microrelief and moisture conditions in different parts of catena serve as a factor responsible for the slightly expressed differentiation of the soil cover. Being located in differently elevated parts of loam catena, the plots revealed quite different water distribution. As compared to plot 1 the rainfall runoff was decreased in plot 2 due to the influence of the capillary fringe of the ground water; plot 3 had an increased surface runoff and in the dried period (June–July) the water content in the soil profile and especially in its lower part proved to be higher than that in the other plots. The soil displayed weakly expressed features of hydromorphism. The morphological description of soil by means of tensiometers showed that the signs of gleying were observed already at a depth of 50–60 cm (Fe–Mn patches, rare dark-gray small mottles and stripes).

The available differences in morphogenetic and water-physical properties of automorphic and weakly-hydromorphic soils have an influence on the soil moisture storage and its dynamics. However, this influence is of minor significance. As seen from Fig.1, in the extreme dried period the difference in the soil moisture storage within the 0–30 cm layer ranged from 102 to 118 mm, i.e. 15–16 mm or about 5 cm (3.1%) for every 0–10 cm soil layer. In the dry and wet periods it was possible to observe the same situation in the 0–50 soil layer: 180–185 mm in the dry period and a somewhat higher amount in the wet period. Insignificant influence of this soil on the water content and its storage should be also explained by the even particle-size distribution along the soil profile.

Let's consider the dynamics and peculiar changes in the water content within the 0–30 and 50–100 cm soil layers in time, i.e. from seeding (May 8) to middle-October (Fig. 2). As it was mentioned above, the water content in the 0–30 layer was decreased as affected by relief pattern and the groundwater level. The peculiar change in the soil moisture storage was observed in all the test plots during the vegetation period. In Mai the weather was rather hot and without rainfall. The water content in the 0–30 cm layer decreased in plots 1 and 2 from 59.4 and 70.0 to 52.3 and 58.8 mm respectively; plot 4 revealed its increase as affected by the groundwater level at a depth of 50 cm. To the end of Mai (28 and 29 Mai) the rainfall (about 20 mm) was conducive to increasing the water content in the 0–30 cm layer of all the plots to 80.8, 79.8, 82.5 and 84.5 mm respectively. The water content in the 50–100 cm layer was minimal in plot 1 and maximal in plot 4 accounting for 130.2 and 185.8 mm respectively, the latter being decreased to 144.5 mm in plot 4 during the dry season from Mai to August. In this period the rainfall in the amount of 22.6 mm didn't influence on the water content even in the topsoil. The soil moisture storage in the 0–30 cm layer showed a decrease to 26.9, 27.5, 44.0 and 30.5 cm or 25.5, 26.1, 41 and 29% of MWC.

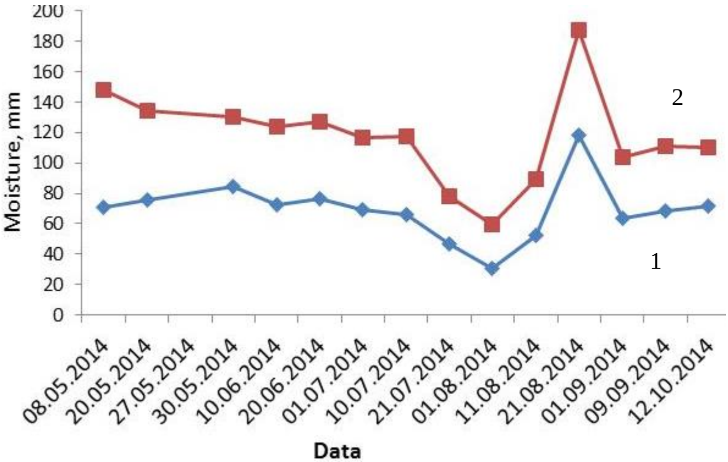

Fig. 2. The dynamics of moisture storage in the 0–30 cm (1) and 0–50 cm (2) layers of the soddy-podzolic soil in plot 4.

The latter was also decreased in the 0–100 cm soil layer during the dry period and made up 137.5, 133.8, 203.1 and 155.0 mm. It corresponds to 41, 40.5, 51 and 47% of MWC and confirms the significant water deficiency within the 0–100 cm soil layer. In the lower boundary of the layer at a depth of 80–90 cm the soil moisture made up 11.9. 11.4, 16.0 and 13.0% in all the test plots respectively. It is insignificantly higher than the maximal hygroscopic moisture (plot 3) and lower than the moisture wilting (14.0%) in the other plots. The very low values of soil moisture were observed on July 21: 10.4, 9.5, 13.5 and 10.6%. Within the topsoil the water content was also rather low, i.e. significantly lower than the maximal hygroscopic moisture (MHM). The identical situation took place in 1972 and 2010 when the drought caused the decrease in the water content within the 0–100 cm layer to the values of MHM and MW. According to Mozhaiskiy (2011) in 2010 the water content in the 0–60 cm layer of the soddy-podzolic soil was decreased to the maximal hygroscopic moisture and didn't exceed the moisture wilting (MW) at a depth of 70 cm. In 1972 the water content in the 0–30 cm layer was estimated at 5.6% (MW – 9.0%), in the 30–50 cm layer – 8.3% (MW– 12.3%), in the 50–70 cm layer – 12.8% (MW–17.1%) and in the 70–100 cm layer – 14.0% (MW– 18.2%). Thus, the soil moisture storage revealed a decrease to the values of MHM in the 0–50 cm soil layer and to MW in the 90–100 cm layer in 1972, 2010 and 2014. Such a severe drying can be observed only in loam-sandy soils within the dry-steppe zone [7]. The dried period of 2014 doesn't yield to that in 1972 and 2010. The boring to the depth of 2 m didn't have a positive effect because the groundwater level seemed to be rather lower.

The rainfall in the period from 7 to 22 August 2014 (about 84 mm) increased significantly the water content to 47, 50, 59 and 52 mm in the 0–30 cm soil layer and to 176, 179, 224 and 207 mm in the 0–100 cm layer in four plots respectively. However, these values didn't reach the lower boundary of optimal moistening that accounts for 73.6 mm and 230.6 mm in the 0–30 and 0–100 cm layers if the MWC is 70%. In plots 1, 2 and 4 the increase in the water content made up 22 mm, while in plot 3 – 15 mm. The soil moisture storage in the 0–100 cm layer revealed an increase to a considerable extent and accounted for 38, 44, 20 and 52 mm to be equal to the water supply of plants in the range from 75 to 96% of MWC. At the end of the vegetation period the soil moisture storage in the 0–100 cm layer made up 109 mm in plot 1, 118 mm in plot 4. Since August 22 to September 1 there was no rainfall and the soil moisture storage in the 0–30 cm layer showed a decrease from 67 to 59% of MWC.

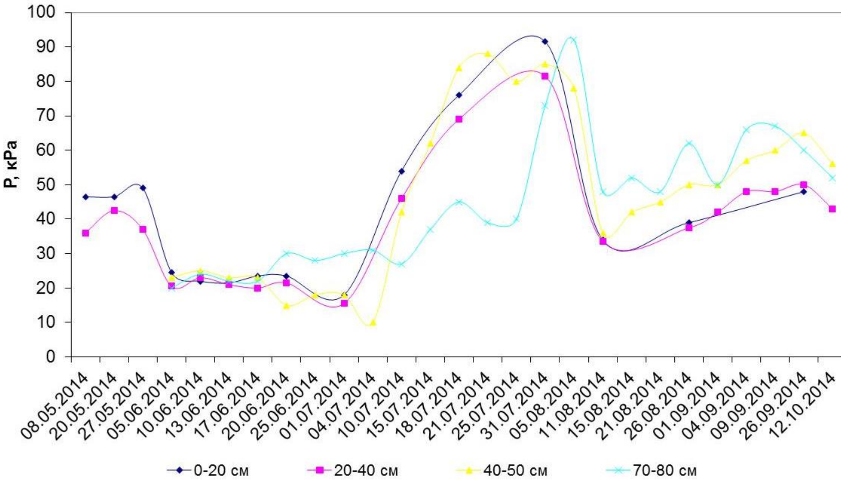

Fig. 3. The dynamics of water potential in different soil layers within the trial field, test plot 4.

The dynamics of water potential was evaluated with account of changes in the soil moisture storage, the water supply of plants – by means of comparing the water potential with its critical value taken as 30, 35 and 40–43 kPa for 0–10, 30–50 and 50–80 cm layers.

The peculiar feature for the dynamics of water potential is its decrease with depth due to increasing the water content because of declining the total evaporation and the influence of the ground water [5]. At the end of Mai and early June the water potential was relatively high throughout the soil profile and exceeded insignificantly the critical values. After rainfall in the amount of 18 mm on June 20 it was declined to 10–20 kPa and seemed lower than the critical value.Up to August 7 there was no rainfall and no positive effect on the moisture even in the uppermost part of the soil.

During the dried period the water potential revealed an increase and reached 78–62 in test plot 2, 79–20 in the test plot 4 and 89–67 kPa at a depth of 50 cm. Its value didn’t exceed 40–45 kPa within the 70–80 cm soil layer in plot 4, being increased to 100 kPa in early August (the capillary potential measured by tensiometer). On August 7 and 8 the rainfall (46 mm) promoted decreasing the water potential to 30 kPa in 0–20 and 20–40 cm layers and to 40–50 kPa in 40–50 and 70–80 cm layers. It follows from this fact that the precipitation in the amount of 46 mm seemed insufficiently high for wetting the soil to the depth of 80 cm; the water potential decreased to the critical value within the 40–80 cm soil layer. During August and September the dynamics of water potential repeated peculiar changes identical to those taken place in June–July. In this period the rainfall in the sum of 20.2 mm (August 17) and 16.8 mm on 9 September had no effect on the water potential, equaled to 40–50 kPa in the 0–20 and 20–40 cm layers and 50–65 kPa in the 40–50 and 70–80 cm soil layers, thus showing a tend to decreasing at the end of September.

Hence, the dynamics of water potential is found to be confirmed with changes in the soil moisture. The severely dried profile of the soddy-podzolic soil cannot be moistened by the short-term rainfall to the depth of 80 cm and the water potential is decreasing to its critical values. The gradient of water potential tends downwards, i. e. its values are higher in the upper soil layers, which are wet to a lesser extent as compared to lower ones.

CONCLUSION

Summarizing the results obtained to study the dynamics of soil moisture storage and water potential, it seemed reasonable to draw the following conclusions.

All the meteorological parameters under study are interrelated and interdependent between each other. For instance, the rainfall decreases the direct solar radiation and the total evaporation to zero, the air temperature is also decreased but the moisture reveals an increase. The wind intensification leads to appreciable increasing the total evaporation and declining the air moisture.

The soil moisture storage and the water supply of rape with perennial sainfoin {*Leguminosae*) are formed as affected by atmospheric precipitation and the vadose water periodically occurring over the compacted soil layers during the rainfall in the vegetation period. The soil-ground water doesn't exceed 3 m (from the day surface) as averaged for several years.

The soil moisture storage is most dynamic in the upper 0–30 and 0–50 cm layers enriched with plant roots. The differences in the dynamics of the soil moisture storage in test plots are explained by their position along the catena being especially appreciable during the prolonged dried period. The influence of morphogenetic and water-physical soil properties is of minor importance. In the course of our studies the dried period was conducive to decreasing the water content in the upper (0–30 cm) soil layer to maximum hygroscopicity and to the values lower than the moisture wilting in the 0–50 cm layer. The test plots 4 and 3 were better supplied with water and the total yield of the dry biomass in these plots seemed practically equal accounting for 250 g/m^2, whereas 200 g/m^2 in plot 1 and 230 g/m^2 in plot 2.

The dynamics of water potential in soil well agrees with the dynamics of soil moisture and its storage. The gradient of water potential tends downwards, i.e. its values are higher in the upper soil layers being moistened to a lesser extent as compared to the lower layers. During the prolonged dried period its values made up 100 kPa in lower 70–80 cm soil layers, what is coincided with the upper limit of tensiometer.

REFERENCES

1. *Hosseini S.M., Mir M., Ganjian N., Pisheh Y.P.* Estimation of the water retention curve for unsaturated clay, *Can. J. Soil Sci*, 2011, Vol. 91, No 4, pp. 543–549.

2. Mazhaiskii Yu.A., Muromtsev N.A., Semenov N.A., Tselekovskaya Z.I. Osobennosti vodnogo rezhima kul'tury zemlyanika na dernovo-podzolistoi pochve v anomal'no zasushlivom godu, *Sovremennye energo i resursos-beregayushchie ekologicheski ustoichivye tekhnologii i sistemy sel'skohkho-zyaistvennogo proizvodstva*, 2011, Vol. 9, pp. 491–499.

3. *Meliorativnaya entsiklopediya*. M.: Rosinformagrotekh, 2003, T. 1, pp.622. 2004,T. 3, pp.10–11.

4. Muromtsev N.A. Energeticheskie aspekty potrebleniya pochvennoi vlagi rasteniyami, *Bulleten Pochvennogo instituta im. V.V. Dokuchaeva*, 2002, Vol. 56, pp.9–12.

5. Muromtsev N.A. Formirovanie i sostoyanie vlagi v kapillyarnoi kaime dernovo-podzolistoi pochvy pri voskhodyashchem potoke iz gruntovykh vod, *Bulleten Pochvennogo instituta im. V.V. Dokuchaeva*, 2005, Vol. 57, pp.50–57.

6. Muromtsev N.A., Kovalenko P.I., Semenov N.A., Mazhaiskii Yu.A., Yatsyk N.V., Shuravilin A.V., Voropai G.V., Anisimov K.B., Kolomiets S.S. *Vnutripochvennyi vlagoobmen, vodopotreblenie i vodoobespechennost' mnog-oletnikh kul'turnykh travostoev.* Ryazan', 2013, 300 s.

7. Muromtsev N.A., Shuravilin A.V., Semenov N.A., Anisimov K.B., Tabuk Musalem. Vliyanie vodoakkumuliruyushchego sloya na vla-goobespechennost' kartofelya na supeschanykh pochvakh Omana, *Bulleten Pochvennogo instituta im. V.V. Dokuchaeva*, 2014, Vol. 73, pp.69–85.

8. Prokhorova Z.A., Frid A.S. *Izuchenie i modelirovanie plodorodiya pochv na baze dlitel'nogo polevogo opyta*. Moscow: Nauka, 1993, 189 h.

9. Sorochkin V.M., Sheptukhov V.N. Izmenenie fiziko-mekhanicheskikh svoistv dernovo-podzolistoi suglinistoi pochvy pri okul'turivanii, *Pochvovedenie*, 1981, No 7, pp.63–66.

10. Sudnitsyn I.I. *Dvizhenie pochvennoi vlagi i vlagopotreblenie rastenii*. Moscow: Izd-vo Mosk. un-ta, 1979, 254 p.